Interactions Between the Cinnabar Moth and Tansy Ragwort

by
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One may ask oneself whether a study on a particular species or on the interaction between species in the original habitat can contribute to the biological control of that species in a totally different environment where it has become a pest problem; or in other words: what can the study of a weed species and of its consumers in the original habitat contribute to the solution of the pest problem in another area?

The species will occupy niches in the two communities that will not be the same. They will have different relations with other organisms and they will find themselves in different abiotic environments. Predictions are therefore risky. Moreover, a study within the natural range of a species will usually provide information only on populations that have succeeded in surviving. It will show under what conditions populations will persist and not how they may be controlled or suppressed completely.

Nevertheless three aspects have to be considered in the natural range.

1. Information is needed on the population dynamics of the pest species in both the new and the original range to detect the vulnerability of its different stages in order to determine the strategy for control.
2. In selecting species as potential controllers the original habitat has to be visited. Preliminary experiments to determine the qualitative and quantitative aspects of the impact of a species can best be done together with host-specificity tests.
3. The third study can take place at a moment when the pest species is already being controlled. It is the gathering of detailed knowledge about the ecological aspects of the relation between controller and controlled, together with studies of the species that were not successful in controlling the pest. Such information is necessary to build a framework of the fundamentals for biological control.

The studies of Dempster and of myself, and of course also those of Judy Myers, fall in the third category although the latter are made in the new environment.

Ragwort is an abundant species in The Netherlands but it does not give us any serious trouble. In agricultural grasslands it is very scarce. A study by the Agricultural University of Wageningen on grassland species records it from only 2% of the 1600 grasslands checked all over the country (Kruyne *et al.*, 1967). Ragwort has almost exclusively been found on grasslands in dry areas whereas the majority of the Dutch grasslands lies on wetter soils.

The weed finds its main distribution in the coastal dunes. Although dune grasslands have been used for sheep grazing in the past this is not in practice any more.

Our study was not aimed at biological control purposes. The relation between the Cinnabar Moth and Ragwort attracted, and still attracts, attention because of the periodic defoliation of the food plant. This is a very striking phenonomenon because it is often complete and happens synchronously over large areas. It may result in mass migration and starvation of very many caterpillars. On one single dune slope we observed thousands of migrating caterpillars, which were not able to reach the top of this slope, and since all of them persisted in crawling in the same direction, most of them eventually died. Further, the very conspicuous colouration and the position of the larvae on their food plants have always given to rise to extensive descriptions and to speculations on selective value.

Lastly, because of the proportion of defoliation the fate of these food plants has intrigued many a man too.

THE INFLUENCE OF INSECTS ON PLANT NUMBERS AND COVER

From earlier studies of Dempster (1971) and myself (1971) it appeared that in spite of the apparent catastrophe among the Ragwort population many defoliated plants regenerated afterwards, either the same season or the next. Population counts revealed that in the plant's range of origin the impact on its density is by far not what could

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be expected on account of the observed attack. Since these studies were made, we began to follow up a hundred sampling sites. In the Dutch dunes Ragwort is distributed over more or less clearly separated subpopulations or pockets ranging in size from less than a hundred square meters to over a thousand. The relief structure of the dunes with north and south slopes adds to this distribution pattern. In order to get an impression of what happens after some years of insect attack on a much wider scale than one or two subpopulations we started this study in 1973.

Besides counts of individual plants the percentage cover by Ragwort was estimated and it is assumed that cover gives a measure for the amount of food present which is more adequate than the number of plants.

When comparing attacked subpopulations with non-attacked ones we see that after one year of attack there is a relative decrease in cover percentage of 32% in the attacked group (Table I). After two years of continued attack the decrease is 39% and after three years the decrease is already 54%. So even in the natural habitat continued attack leads to a reduction in the amount of plant material.

Extinction of Cinnabar Moth populations is by far not a rare phenomenon (the same does for Ragwort populations). Since 1973 the Cinnabar Moth vanished from quite a number of local plant populations. At the same time other Ragwort populations became inhabited by the insect.

Table I Relative cover percentage of Ragwort in populations attacked by the Cinnabar Moth as compared with non-attacked populations (relative cover in each year: 1.00)

period of attack	number of populations	relative cover	decrease (%)
1 year	62	0.68	32
2 years	26	0.61	39
3 years	10	0.46	54

Table II shows what happened during the four years of observation:

1. a number of Cinnabar Moth populations vanished
2. a number of Cinnabar Moth populations survived
3. a number of Ragwort sites became inhabited by the moth
4. a number of Ragwort sites was never attacked

When we look at the food situation in these four categories, we see that the abandoned Ragwort sites show the lowest relative cover, whereas those recently inhabited show the highest cover. Subpopulations with continued attack are intermediate. The non-attacked subpopulations have a relatively high cover, but lower than the recently attacked ones.

The situation in 1976 shows that about half of the Cinnabar Moth populations existing in 1975 became extinct. Plant cover in the surviving populations was 3.4 times higher than in the abandoned ones. This illustrated once more the importance of the food plant in the population dynamics of the insect.

The fate of an abandoned Ragwort subpopulation is a relative increase again, a recovery. Twenty-two of such Ragwort sites showed an increase to 136% one year after the last attack as compared with the group of plant populations which was never attacked by the Cinnabar Moth.

The process illustrated here contains the hazards of walking on ice floes, like jumping from one floe to the other. Cinnabar populations reduce plant cover and become extinct; some individuals can reach other plant populations. After animal extinction there is a regeneration of plant cover.

Table II Survival and extinction of the Cinnabar Moth in Ragwort subpopulations

oviposition in subpopulations of Ragwort			number of sites	relative cover in spring 1976	Cinnabar Moth attack (= oviposition) in summer 1976	
1973	1974	1975			+	−
+	−	−	17	0.24	1	16
+	+	−				
+	+	+	10	0.59	6	4
−	+	+	29	1.51	15	14
−	−	+				
−	−	−	31	1.00	4	27

18 out of 39 Cinnabar Moth populations vanished (46%)

THE INFLUENCES OF THE FOOD PLANT ON INSECT AND STRATEGIES FOR SURVIVAL

How does the individual insect function in this process? What strategies for survival can be distinguished? Some aspects of the life cycle of the insect will be considered from this point of view, mainly aspects of behaviour and distribution pattern.

a. The important role of plant cover is reflected in the positive relation between oviposition and cover percentage (Van der Meijden, 1974) (see Table III).

Table III Oviposition and Ragwort cover percentage

plant cover	number of populations	number attacked
<15%	41	5 (12%)
>15%	52	24 (46%)

Apparently individual females do not always lay their eggs in the plant population where they spent their lives as caterpillars, but there is a redistribution in which plant cover, i.e. the amount of food present, plays an important role.

b. Ragwort populations in shaded areas, in this case woods of Poplar, Birch and Hawthorn, are often not inhabited by the Cinnabar Moth. When caged moths are given the opportunity to choose between plants in the sun and plants in the shade, there is a significant preference for the plants in the sun. This might contribute to survival in two ways. Firstly, the distribution of one of the most ferocious predators of the caterpillars, the Red Wood Ant, is linked to the shaded areas. Secondly, there is a very pronounced relation between the rate of development of eggs and larvae and temperature (see Table IV), and also with survival.

Mean temperature in the shady areas is considerably lower than in the open areas. This causes a retardation of growth. Rapid growth, however, is advantageous because of the vulnerability of especially the larval stage compared with the pupal stage (Dempster, 1971).

Table IV Rate of development of the Cinnabar Moth in days

temperature in °C (night-day)	stage eggs	stage larvae	total duration
5 (0-10)	no hatching		
10 (5-15)	25	102	127
15 (10-20)	12	55	67
20 (15-25)	8	27	35
25 (20-30)	6	22	28
30 (25-35)	6	20	26

c. Large plants receive on the average more egg batches than smaller ones, which means more eggs per plant. The mean size of the egg batches, however, is not different over the different plant sizes. When rosette plants are compared with flowering plants, the latter category contains proportionally many more plants with egg batches. Therefore, plant size i.e. a measure for biomass, as well as plant quality affect egg laying. There is a relation with the number of batches and the total number of eggs, but not with the number of eggs in each batch (Van der Meijden, 1976).

The majority of small-sized plants is never chosen for oviposition. This may be a mechanism to avoid mortality during the younger instars: temporary food shortage during these instars may have a negative effect, as was shown by Dempster (1971). Young larvae are not able to cover large distances in search of undefoliated plants. Egg laying on large plants therefore is advantageous because the chance of *early* defoliation is small.

The selection of flowering plants for oviposition may be related to the fact that a diet with flowers or flowerbuds leads to a much higher percentage of emergence of the pupae and a higher fecundity (Van der Meijden, 1976).

Since defoliation results in regenerated plants which are initially smaller than not defoliated plants, the preference for egg laying on large plants and on flowering plants may add to the redistribution of the Cinnabar Moth over the different subpopulations.

d. Oviposition takes place at the underside of the lower leaves. Feeding of the young larvae normally starts on the leaf where they hatched. Since defoliation by the older larvae normally starts with the flowers and top leaves, the vulnerable eggs and young larvae are protected from being killed through action of older congeners.

e. Eggs are laid in batches and the larvae hatching live gregariously during the first and part of the second instar. It appears that individual survival chance up to the second instar is linked to batch size. Most of the mortality among eggs and younger instars is caused by predation and it is thought that living gregariously reduces predation through an escape reaction (Dempster, 1971; Van der Meijden, 1976).

f. From the second instar onwards larvae start to disperse. This dispersal behaviour can be divided into two phases. The first phase is a dispersal over the plants on which the eggs were laid, the second phase a dispersal over the remaining plants within or outside the original subpopulation.

The first phase in dispersal—over the original food plant—is accompanied by a change of diet from leaves only in instar 1 to leaves and flowers or flowerbeds in the older instars.

The second phase, the dispersal over different plants is characterized by a selection for generative plants and for large plants. I mentioned already the importance of a diet with flowers or flowerbuds for emergence success and fecundity.

The dispersal over different plants is a very conspicuous process during the mass migration in situations of food shortage, but even when food is not yet in short supply larvae may leave their food plants. In laboratory experiments we could demonstrate that this dispersal is density dependent.

We have tried to get some insight into the importance of the latter dispersal, i.e. when food is not in short supply by rearing caterpillars in such a set-up that dispersal was prevented.

In one experiment larval density was constant in time: either 1, 2, 4, 8 or 16 larvae were reared per jar with plenty of food. Female pupae resulting from these rearings differed in size. Females having grown up at high densities were much smaller than the solitary one. Like in many other insects, pupal size is a measure for fecundity. Larval mortality was especially high at the highest densities, so apparently crowding has a negative effect on individual pupal parameters as was also shown by Dempster (1971) for this species.

A second experiment was set up to determine in what instar the negative influences of high density appear and what the impact may be in more realistic density situations. Again the group of larvae that was reared at high density during all instars showed the most pronounced effect. But there is also a slight negative influence on pupal diameter of larvae that were exposed to high densities during a shorter period (Van der Meijden, 1976).

CONCLUSIONS

Apparently the Cinnabar Moth does not live in a balanced relation with the subpopulations of its food plant. It reduces its food and hence local insect populations may become extinct. Through dispersal of moths as well as older larvae new subpopulations may become inhabited. Presumably on a much wider scale some balance exists.

Within the insect population a number of strategies possessing survival value can be demonstrated. The density dependent processes in migration of the older instars are not adequate to reach a balance. They do not lead to a more sophisticated use of food, but undoubtedly they add to the survival of some individuals.

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